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Comparing Methods to Determine Cetane Ratings of Fuel Blends

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TOPICS

- **Introduction**
  - What is a Cetane Rating?
  - How is it currently determined?
- **Methodology**
  - Engine method
  - Traditional laboratory method
  - Newer laboratory method
- **Comparison test**
  - Fuels used
  - Results
- **Recommendations**

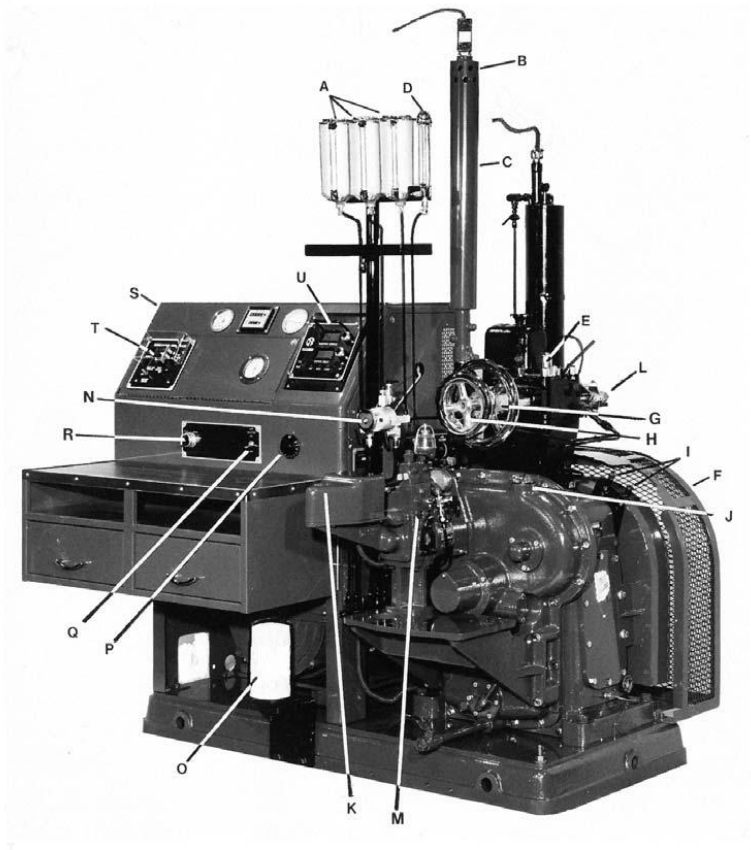
What is a Cetane Rating?

- **Cetane rating is a measure of the speed at which a given fuel combusts**
  - There is a delay between the time the fuel is injected and it begins to combust; this is known as the ignition delay time
  - During this ignition delay time, the fuel will volatilize and disperse into the compressed air in the combustion chamber
  - When the conditions are “right”, the fuel will spontaneously begin to combust
  - The ignition delay time can vary from fuel to fuel depending on fuel composition, as well as engine design and operational parameters
- **“Low cetane” fuels have a long ignition delay time**
- **“High cetane” fuels have a short ignition delay time**

How is Cetane Traditionally Determined?

- **The original method to determine cetane rating uses a research engine**
  - This test is lengthy and expensive
  - It requires expert technicians to operate the engine
  - ASTM D613
- **Subsequent laboratory methods were developed to improve response time**
  - Two-variable test method
    - Uses API gravity and T_{50} temperature
    - ASTM D976
  - Four-variable test method
    - Uses density, and the T_{10}, T_{50}, and T_{90} temperatures
    - ASTM D4737

What is the Engine Method?



- **Requires the user to adjust the compression ratio of the test engine while in operation per ASTM D613**
- **Uses two reference fuels as limits**
- **User interpolates subject fuel between the brackets**
- **Directly measures the Cetane Number of a diesel oil fuel**

What are the Traditional Laboratory Methods?

- **Two-variable method**
  - ASTM D976
  - Uses the API Gravity of the fuel along with the mid-boiling point (T_{50})
  - Uses a simple calculation that has been refined over many years of petroleum-based fuel testing
  - Insensitive to the addition of cetane-improving additives, pure hydrocarbons, and synthetic fuels
  - Has a correlated range of 30 – 60 Cetane Number
- **Four-variable method**
  - ASTM D4737
  - Uses the fuel density and three boiling point temperatures (T_{10}, T_{50}, and T_{90})
  - Uses a simple calculation that has been refined over many years of petroleum-based fuel testing
  - Has a correlated range of 32.5 – 56.5 Cetane Number

What is the Newer Laboratory Method?

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- **Ignition Quality Tester (IQT)**
  - Automated lab test covers conventional diesel fuel, oil sands fuel, fuel blends, etc.
  - Is applicable for fuels with cetane-improving additives
  - Yields the Derived Cetane Number (DCN) per the ASTM D6890 test method

Comparison Testing

- **Test fuels**
  - Five base fuels: Biodiesel (FAME), JP-8, Synthetic Paraffinic Kerosene (SPK), GTL diesel fuel, and Ultra-Low Sulfur Diesel (ULSD)
  - Blends were created
    - Various ratios of base fuels (binary blends and tertiary blends)
    - With and without cetane improver (two levels of treat rate)
- **Test fuels subjected to all four methods of cetane evaluation**
  - DCN obtained from an additional laboratory as a Round Robin test
- **Results from laboratory methods compared back to research engine method results**

Research Engine method (ASTM D613) → Cetane Number

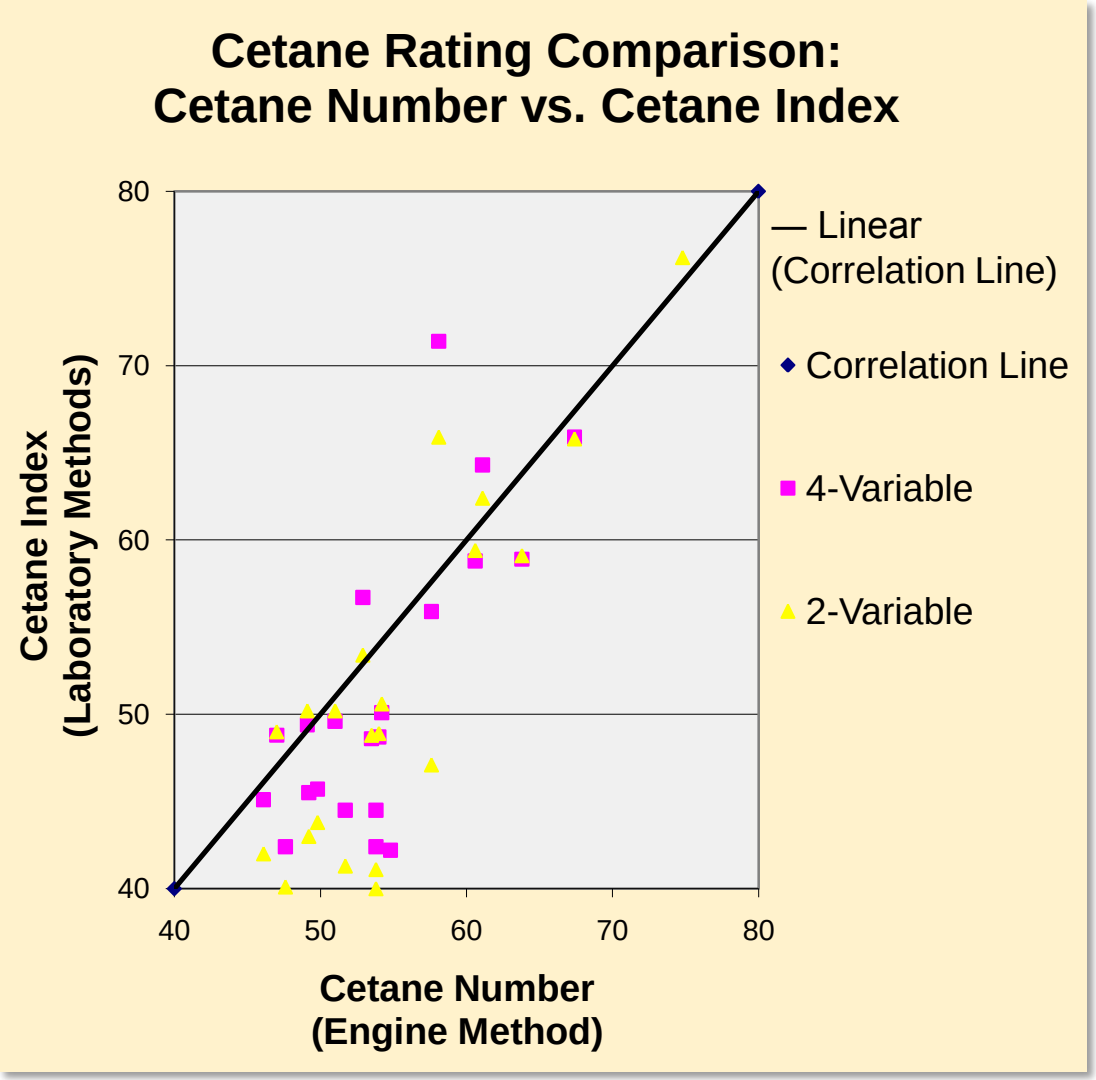
2- and 4-Variable methods (ASTM D976 and D4737) → Cetane Index

IQT method (ASTM D6890) → Derived Cetane Number

Data Table of Test Results

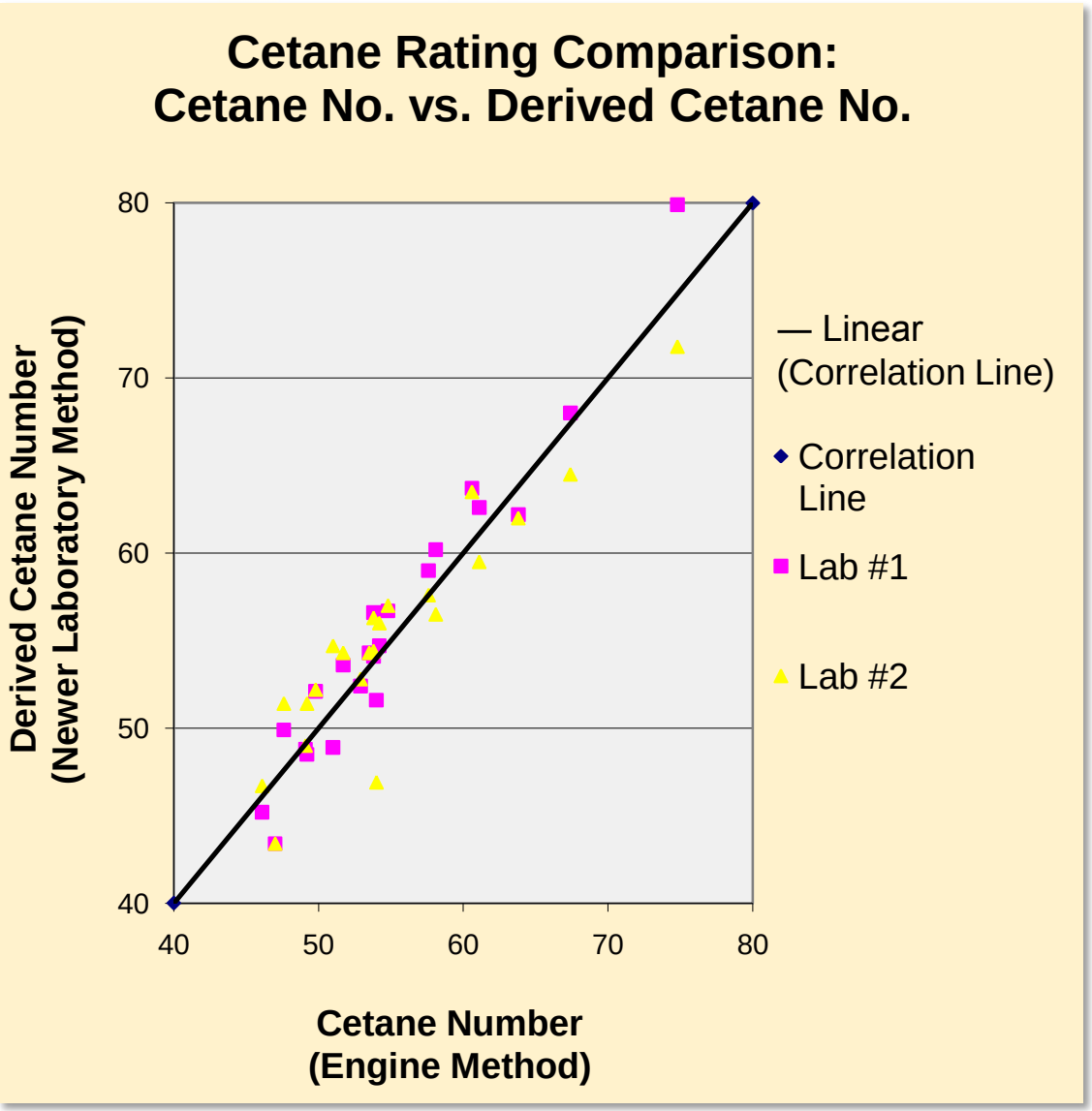
Fuel	Traditional Laboratory Methods CETANE INDEX D4737	Traditional Laboratory Methods CETANE INDEX D976	Engine Method CETANE NO. D613	Newer Laboratory Method DERIVED CETANE NO. D6890 (Lab #1)	Newer Laboratory Method DERIVED CETANE NO. D6890 (Lab #2)
Biodiesel	55.9	47.1	57.6	59.0	57.6
JP-8	45.1	42.0	46.1	45.2	46.7
SPK	71.4	65.9	58.1	60.2	56.5
GTL diesel fuel	82.2	76.2	74.8	79.9	71.8
ULSD	48.8	49.0	47.0	43.4	43.4
JP-8 : Biodiesel (4:1)	42.4	40.1	47.6	49.9	51.4
JP-8 : Biodiesel (4:1) + Cetane Improver (max treat rate)	42.2	39.8	54.8	56.7	57.0
JP-8 : Biodiesel (4:1) + Cetane Improver (min treat rate)	42.4	40.0	53.8	54.1	54.4
JP-8 : GTL fuel (1:1)	58.9	59.1	63.8	62.2	62.0
JP-8 : GTL diesel fuel : Biodiesel (2:2:1)	58.8	59.4	60.6	63.7	63.5
JP-8 : GTL diesel fuel : Biodiesel (8:1:1)	45.7	43.8	49.8	52.1	52.2
JP-8 + Cetane Improver (max treat rate)	44.5	41.1	53.8	56.6	56.3
JP-8 + Cetane Improver (min treat rate)	44.5	41.3	51.7	53.6	54.3
SPK : JP-8 (1:1)	56.7	53.4	52.9	52.4	52.8
SPK : JP-8 : Biodiesel (1:8:1)	45.5	43.0	49.2	48.5	51.4
SPK : JP-8 : Biodiesel (2:2:1)	50.1	50.6	54.2	54.7	56.0
SPK : JP-8 : GTL diesel fuel (1:1:2)	65.9	65.8	67.4	68.0	64.5
SPK : JP-8 : GTL diesel fuel (1:2:1)	49.6	50.2	51.0	48.9	54.7
SPK : JP-8 : GTL diesel fuel (2:1:1)	64.3	62.4	61.1	62.6	59.5
ULSD : Biodiesel (4:1)	49.4	50.2	49.1	48.8	49.0
ULSD + Cetane Improver (max treat rate)	48.6	48.8	53.5	54.3	54.3
ULSD + Cetane Improver (min treat rate)	48.7	48.9	54.0	51.6	46.9

Comparison Testing: Traditional Laboratory Methods vs. Engine Method



- Most fuel blends do not correlate well with engine test
- Especially true at Cetane Rating = 50 +/- 5

Comparison Testing: Newer Laboratory Method vs. Engine Method



- Results from DCN testing correlate very well with research engine results
- Lab #1 and Lab #2 also in good agreement

Conclusions

- **Traditional laboratory methods for determining Cetane Index**
  - Based on TARDEC test results, these methods are not suitable for use with fuel blends, including synthetic fuel blends, and fuels or fuel blends additized with Cetane improvers
    - Results do not correlate well to engine testing
    - Includes 2- and 4-variable methods (ASTM D976, D4737)
- **Newer laboratory method for determining Derived Cetane No.**
  - Based on TARDEC test results, this method is suitable for use with fuel blends, including synthetic fuel blends, and fuels or fuel blends additized with Cetane improvers
    - Results correlate well to engine testing

Recommendations

- **In the future, we will be handling unconventional fuels and fuel blends**
- **Some or all of these fuels may have synthetic components**
- **Future fuel evaluations should**
  - Disregard 2- and 4-variable methods (ASTM D976 and D4737) to determine a fuel's Cetane Index because of the poor correlation of these methods with the research engine method
  - Incorporate the IQT method (ASTM D6890) to determine a fuel's Derived Cetane Number because of the very good correlation of this method with the research engine method
- **Future standards and specifications should be changed to reflect this method change**

Back-up Slides

Additional Chart - Test Results

- 2- and 4-variable methods are insensitive to biodiesel addition and/or Cetane improver addition
- Engine and IQT methods track very closely with each other